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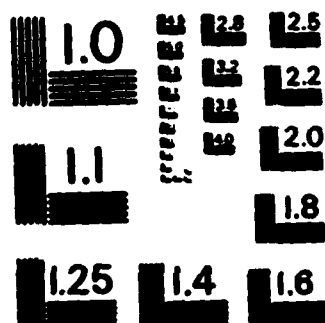
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Refurbishing "Spray on" Aluminum Enamel on Proximity Clothing

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19 ABSTRACT (Continue on reverse if necessary and identify by block number) This report covers the effectiveness of refurbishing the aluminum coating on worn aluminized proximity firefighter's clothing. The intent was that if a "spray-on" aluminum enamel could restore the surface aluminum coating to an acceptable level of infrared radiant heat reflectance then the clothing could be worn for an extended period, thus, reducing replacement costs, and extending the "safe use-life" of proximity firefighter's clothing.			
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PREFACE

This report was prepared by the Navy Clothing and Textile Research Facility, 21 Strathmore Road, Weymouth, MA 01760, under NIFB-W-82-29, for the Air Force Engineering and Services Center, Engineering and Services Laboratory (AFESC/ED) Tyndall AFB, FL 32403.

This report summarizes work done between October 1982 and September 1983. AFESC/EDCS project officer was Mr. Joseph Walker.

This report covers the effectiveness of refurbishing the aluminum coating on worn aluminized proximity firefighter's clothing. The report does not constitute an indorsement or rejection of any specific piece of equipment for Air Force use nor can it be used for advertising a product.

This report has been reviewed by the Public Affairs Office (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nationals.

This technical report has been reviewed and is approved for publication.

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SECTION I

INTRODUCTION

A. OBJECTIVE

The Navy Clothing and Textile Research Facility studied the effectiveness of refurbishing the aluminum coating on worn aluminized proximity firefighters' clothing. It was thought that, if a ~~spray-on~~ aluminum enamel could restore the surface aluminum coating to an acceptable level of infrared radiant heat reflectance, then the clothing could be worn for an extended period of time, reducing replacement costs. Vacuum-deposited aluminum fabric specimens were cut from worn firefighters' clothing and tested for their thermal transmission at three levels of heat flux. Before heat-testing, each specimen was identified as to its percentage of infrared reflectance at 1100 nanometers and, subjectively, by visually observing the worn aluminized surface. This report describes the laboratory investigation of two ~~spray-on~~ aluminum enamel coatings over worn aluminized fabric to obtain data that would allow a judgment as to their effectiveness, as well as the effectiveness of all ~~spray-on~~ aluminum enamel, to extend the ~~use-life~~ of proximity firefighters' clothing.

B. BACKGROUND

A new aluminized proximity firefighters' garment has a highly reflective outer coating of vacuum-deposited aluminum on 1/4 mil polyester film, applied to both the front and back sides and laminated to the fabric with a suitable adhesive. Another way was to vacuum-deposit the aluminum on a thin film that was

removed after the aluminum coating was transferred to adhesive coating on the base fabric. In either case the aluminum coatings are fragile and easily compromised. When new, the aluminized garments exhibited over 92 percent infrared reflectance, which quickly declines in use. The infrared reflectance is compromised by: creasing, nonvisible surface coatings such as oil or water-carried deposits, abrasion, grease, dirt, paint, and wear and tear. Generally, garments continue to look good for 6 months to 1 or more years, however "use-life" depends on how often the garments are worn and the level of activity at the fire stations. Also, the types of fires the garments are exposed to will affect their ultimate "use-life." Some airfields used aluminum garments exclusively for fighting fuel fires while others used the one aluminized garment for fuel fires as well as structural fires.

In the early 1970s, an Air Force fire station in Florida used an aluminum "spray-on" enamel to refurbish worn aluminum coatings of proximity firefighters' clothing. The fire station had no backup information as to the effectiveness of this coating, as compared to the worn aluminum surfaces it touched up but it was visually difficult to distinguish the touched up area from a new aluminized surface. The use of this "touch-up" aluminum enamel was stopped after the Navy Clothing and Textile Research Facility advised against its use. With the continued increase, however, in the cost of proximity firefighters' clothing, renewed emphasis was placed on improving the cost-effectiveness of the clothing. One way would be by protecting the vacuum-deposited aluminum surface from abrasion and another way would be by refurbishing

the aluminum surface after it is compromised. Development of tougher abrasion-resistant aluminum coatings is currently under study by Arthur D. Little, Cambridge, MA for the Government. This report covers the evaluation of two aluminum enamel "touch-up" kits that can be sprayed on worn aluminum coatings for the purpose of extending the "use-life" of firefighter clothing. Information derived from this study should be valid for other "spray-on" aluminum enamel "touch-up" kits.

SECTION II

MATERIALS

Two Air Force fire stations were contacted and requested to submit their worn aluminized firefighters' clothing (coat and trousers) for test and evaluation. Upon receipt of the clothing, specimens were randomly selected from sections of the clothing that looked very good to very poor. Table I lists each of the classifications used from very poor to excellent along with explanations. After the initial selections, the specimens were tested for percentage reflectance on a spectrophotometer with a wide viewing area. The infrared reflectance values of each specimen were recorded up to 1100 nanometers. Table II lists the specimens tested along with their percentage reflectance at 1100 nanometers. The code number designation given to each specimen represents a visual subjective evaluation, based on how badly the aluminized surface was compromised. Table I lists the code number, along with the corresponding classification and physical description of how the surface of the specimen looked. Table III uses Table I classifications and adds the percentage infrared reflectance limits for each classification. The test specimens were then listed in column form in Table II as to their percentage reflectance. As shown in Table II, some of the specimens coded very poor and fair were listed under poor with the same type of visual mismatches for three of the other five columns. Reliance on grading the worn aluminum coatings was placed on the spectrophotometer values and not on subjective observations.

**TABLE 1. VISUAL DESCRIPTION AND CLASSIFICATION OF WORN
VACUUM-DEPOSITED ALUMINUM COATINGS ON 19-OUNCE
ASBESTOS HERRINGBONE TWILL FABRIC**

CODE NO.	CLASSIFICATION	DESCRIPTION
E	EXCELLENT	Untouched new surface
VG	Very Good	Worn but still looks like new
G	Good	Surface continues to look shiny but duller than very good
F	Fair	Abraded dull surface showing no dirt or grease
P	Poor	About 75 percent of aluminum coating abraded off and moderately dirty or greasy.
VP	Very Poor	Aluminum coating removed or badly abraded off the substrate and definitely dirty - grease, tar, paint, etc.

TABLE 2. CLASSIFICATION OF TEST SPECIMENS BASED ON
PERCENT REFLECTANCE AT 1100 NANOMETERS (CODE
NO/PERCENT REFLECTION)

VERY POOR	POOR	FAIR	GOOD	VERY GOOD	EXCELLENT
(<64.9%) (No/%)	(65-66.9%) (No/%)	(67-69.9%) (No/%)	(70-72.9%) (No/%)	(73-91.9%) (No/%)	(>92%) (No/%)
VP-1/53.4	VP-2/65.3	VP-7/68.4	G-1/71.2	P-3/74.3	01/92.2%
VP-3/64.4	VP-5/66.7	P-10/68.0	G-10/71.7	P-6/76.8	02/92.4
VP-4/55.4	P-5/67.6	F-9/68.3	VG-3/72.0	G-4/75.3	
VP-6/60.1	P-9/66.0	F-10/68.7	VG-5/72.0	G-6/75.0	
VP-8/62.3	F-1/66.1	G-9/68.6	VG-8/71.9	G-7/76.6	
VP-9/63.6	F-6/66.8	G-11/68.4	VG-9/71.4	VG-10/74.5	
Sears/54.4			VG-7/69.7		
Pyrepel®/62.3					

**TABLE 3. PERCENT REFLECTANCE OF SIX CLASSIFICATIONS OF
WORN ALUMINUM COATING SPECIMENS**

CLASSIFICATION	REFLECTANCE (%)
Excellent	>91.9
Very Good	73-91.9
Good	70-72.9
Fair	67-69.9
Poor	65-66.9
Very Poor	<65

Table 4 lists the physical properties of aluminized fabric, insulation liner and vapor barrier material relevant to this study.

Heat-resistant "spray-on" aluminum enamel from two separate manufacturers were used in this study. One "spray-on" aluminum enamel was sold by Sears. It contained nonvolatile barium metaborate, 0.5 percent; aluminum paste (Type II, Class B), 2.4 percent; silicone resin, 6.4 percent; acrylic resin, 2.0 percent. Also, volatile pyrol, 23.9 percent, petroleum distillates, 10.0 percent; methylene chloride, 23.6 percent; isobutane, 17.8 percent; propane, 13.4 percent; tinting color less than 5 percent. The second "spray-on" aluminum enamel came from Pyrepel® Product, Inc., Newark, Ohio and is sold as a touch-up kit to refurbish worn aluminum-coated fabrics. The bright aluminum from Pyrepel® contained 2.4 percent aluminum paste (Type II, Class A), 7.1 percent petroleum resin, 60.5 percent aromatic hydrocarbons and 30 percent propane/isobutane propellant.

Because of the high percentage of volatiles in each of the "spray-on" enamels they can only be effectively used on nonabsorptive materials. If sprayed on an absorbent fabric the volatile hydrocarbons will carry the dissolved silicone and acrylic resins into the fabric, leaving the aluminum on the surface of the fabric from which it is easily rubbed off by simply touching the aluminum. However, this was not the case with aluminized fabrics used in firefighters' clothing. The

aluminized fabric has about a 2 oz/yd² adhesive coating which effectively blocks absorption into the fabric. The "spray-on" enamels were applied to the specimens and allowed to dry for a minimum of 48 hours.

TABLE 4. MATERIALS USED FOR THERMAL TRANSMISSION TESTS

MATERIALS	WEIGHT (OZ/YD ²)	THICKNESS (INCHES)*	DESCRIPTION
<u>Aluminized Fabric</u>			
Base Fabric	19	0.046	Asbestos cotton blend (underwriter's grade) herringbone twill
Aluminum Coating	2	--	3M Co. type 104 transfer film
<u>Insulation Liner</u>			
Lining fabric, Pace	3.2	0.011	Nomex®, pajama check weave material
Low density batt	7.5	0.250	Nomex®, needle punched batting, natural
Lining fabric, back	3.7	0.011	Rayon, 2/1 right-hand twill, black
<u>Vapor Barrier</u>			
Base fabric	2.0	0.008	Nylon taffeta, undyed
Water-resistant coating	3.5	--	Neoprene-coated to one side of nylon taffeta fabric

*Thickness - at 0.1 PSI

SECTION III

APPARATUS AND PROCEDURE

Thermal transmission tests were performed on the experimental prototype Fire Simulator. The apparatus consists of two vertical banks, each containing two radiant heat quartz lamps focused so that the maximum energy falls within a fairly narrow band of about 1 inch wide by about 5 inches long. The voltages to the quartz lamps are individually controlled by variacs and the complete unit is water-cooled, including the plate in front of the hand shutter. The hand shutter allows the quartz lamps to reach maximum operating temperature before exposing the specimens. All testing was performed with a 50-second warmup time and 30-second exposure of the specimen to the infrared radiant heat. The thermal transmission was recorded by the use of a water-cooled heat flux transducer from Midtherm Corp, Huntsville, Alabama, attached to a millivolt recorder. The transducer was centered and placed in contact with the back of the specimens for the single fabrics, as well as when tested in assembly with the insulation liner and vapor barrier. The heat flux at the surface of each specimen was preset at three levels of 0.75, 1.3 and 1.9 gcal/cm²/sec. The use of a 0.75 gcal/cm²/sec infrared energy level was based on a review of the literature. Stoll (Reference 1) suggested that a value of 0.71 gcal/cm²/sec would prevail in an encircling aircraft carrier deck fire. Confield and Russell (Reference 2) measured values of JP-4 fuel fires burning in a rectangular 8-foot by 16-foot pit and obtained a value of about 0.76 gcal/cm²/sec at the edge of the

luminous flame front. Graves, (Reference 3) shows that the heat from fuel fires depends on the size of the fire, the wind velocity, ground conditions, location around the fire and distance from the fire. Changing environmental conditions could vary the heat flux from a high of 7 gcal/cm²/sec to less than 0.1 gcal/cm²/sec. However, a realistic set of parameters (4 feet from the edge of the fire, off to one side, and a fuel diameter of 12 feet, which was found to be nearly the minimum required for maximum radiative emission from fuel fires) exhibited a heat transfer rate of approximately 0.85 gcal/cm²/sec. When considering the three values of 0.71, 0.76 and 0.85 gcal/cm²/sec it was decided to use 0.75 gcal/cm²/sec as the lower limit of heat flux. The value 1.9 gcal/cm²/sec was chosen because it was the heat flux at which Reference Military Specification material is tested and was considered to be the average maximum radiant heat from fuel fires. The middle level of 1.3 gcal/cm²/sec was chosen because it was between the minimum and maximum levels and was used in a number of reports. The specimens were tested three ways: worn aluminized fabric alone; worn aluminized fabric in front of vapor barrier and insulation liner; refurbished worn aluminized fabric alone, first with Sears and then with Fyrepel® "spray-on" aluminum enamel.

SECTION IV

RESULTS

Table 5 data show that the refurbished worn aluminized fabric with Sears "spray-on" enamel was no better than the worst of the worn specimens. Specimens classified very poor and exhibiting reflectance readings of 53.4, 64.4 and 55.4 percent, when tested at a heat flux of $0.75 \text{ gcal/cm}^2/\text{sec}$ showed thermal transmission reading of 0.26, 0.20, and $0.23 \text{ gcal/cm}^2/\text{sec}$, respectfully. When retested after being refurbished with Sears "spray-on" aluminum enamel, the same specimens averaged approximately the same level of thermal transmission. Very poor samples exposed to a heat flux of $1.3 \text{ gcal/cm}^2/\text{sec}$ again showed about the same thermal transmission readings before and after refurbishing. Using Sears "touch-up" kit on specimens classified very good the thermal transmission readings did not improve and were equal to the readings found for the very poor samples. The Fyrepel® "spray-on" aluminum enamel "touch-up" kit was only used on those samples rated very good and exhibited a 7.9 percent increase in reflectance to 62.3 percent as compared to the Sears product at a 54.4 percent reflectance. At a heat flux of $0.75 \text{ gcal/cm}^2/\text{sec}$ the Fyrepel® "spray-on" enamel is significantly better than the Sears product, exhibiting an average thermal transmission of $0.17 \text{ gcal/cm}^2/\text{sec}$, as compared to $0.23 \text{ gcal/cm}^2/\text{sec}$ and is equal to the specimens rated poor. However, at a heat flux of $1.3 \text{ gcal/cm}^2/\text{sec}$ the Fyrepel® product is about equal to an aluminized fabric classified very poor.

Some observations can be made for the worn aluminized fabrics tested in assembly with a vapor barrier material and insulation liner. Aluminized fabrics rated fair should protect the firemen from blister when exposed to a heat flux of 1.9 gcal/cm²/sec for 30 seconds. Stoll-Chianta burn injury curve (Figure 1) shows that if the human skin is exposed to a rectangular radiant heat pulse of 0.1 gcal/cm²/sec the threshold of pain would be reached in 13 seconds and blister would occur in about 33 seconds. The total absorbed energy needed to reach the threshold of pain would be 1.3 gcal/cm² and for blister 3.3 gcal/cm². Table 5 data were not derived from a rectangular heat load, but from an energy curve that showed a gradual and steady increase in thermal energy. The reported data were taken at the end of the 30-second exposure period; the total energy under the curve was not recorded for this report. However, estimates can be made for the threshold of pain and blister for the worn aluminized fabric in assembly with vapor barrier fabric and insulation liner at a heat flux of 1.9 gcal/cm² for 30 seconds. Worn aluminized fabric in assembly with reflectance readings greater than 67 percent (fair) should protect the firemen from burn injury. A thermal transmission reading of 0.13 gcal/cm²/sec should show a total absorbed energy of less than 1.3 gcal/cm² and less than 3.3 gcal/cm² for blister. Those garments with worn aluminized fabric rated poor or less should be considered for replacement.

TABLE 5. THERMAL TRANSMISSION VALUES FOR WORN ALUMINIZED FABRICS BEFORE AND AFTER REFURBISHED WITH "SPRAY-ON" ALUMINUM ENAMELS AT THREE LEVELS OF HEAT FLUX; 30-SECOND EXPOSURES

TEST SPECIMENS	VERY POOR			POOR			FAIR		
	CODE #	gcal/cm ² /sec	0.75 1.3 1.9	CODE #	gcal/cm ² /sec	0.75 1.3 1.9	CODE #	gcal/cm ² /sec	0.75 1.3 1.9
Aluminized Fabric	VP-1	0.26	0.37	VP-2	0.17	0.35	VP-7	0.16	0.36
	VP-3	0.20		VP-5	0.18	0.21	P-10	0.16	0.54
	VP-4	0.23		P-5	0.17		P-9	0.15	0.41
								0.15	0.60
Aluminized Fabric With Insulation Liner Vapor Barrier	VP-8	0.033		P-9		0.33	P-10		0.14
	VP-9		0.24	P-1		0.086	G-9		0.12
	VP-10	0.033	0.054	P-6	0.02	0.072	G-11	0.024	0.037
Refurbished Aluminized Fabric	VP-1	0.24	0.42						
Sears Alum Enamel	VP-3	0.23	0.46						
	Vp-4	0.22	0.33						

TABLE 5. THERMAL TRANSMISSION VALUES FOR WORN ALUMINIZED FABRICS BEFORE AND AFTER REFURBISHED WITH "SPRAY-ON" ALUMINUM ENAMELS AT THREE LEVELS OF HEAT FLUX; 30-SECOND EXPOSURES (CONCLUDED)

TEST SPECIMENS	GOOD			VERY GOOD			EXCELLENT				
	CODE #	gcal/cm ² /sec	0.75	1.3	1.9	CODE #	gcal/cm ² /sec	0.75	1.3	1.9	
Aluminized Fabric	G-1	0.11	0.20	0.48	P-3	0.10	0.25	0.37	01	.043	0.10
	G-10	0.12	0.25		P-6	0.11	0.22	0.35	02	.045	0.13
	VG-3	0.11	0.27	0.41	G-4	0.10	0.21	0.30			
Aluminized Fabric With Insulation Liner Vapor Barrier	VG-5	0.018	0.041		G-6			0.052	01	.001	.014
	VG-8	0.022			G-7			0.027	02		.016
	VG-9			0.058	VG-7	0.019	0.031				
Refurbished Aluminized Fabric Sears Alum Enamel					P-3	0.25	0.38				
					P-6	0.21	0.44				
					G-4	0.20	0.42				
Refurbished Aluminized Fabric Fyrepele Alum Enamel					F-3	0.18	0.38	1.01	02	0.23	0.46
					F-2	0.18	0.30		03	0.17	0.33
					G-8	0.15	0.32				

EVALUATION OF THERMAL PROTECTION--STOLL-CHIANTA

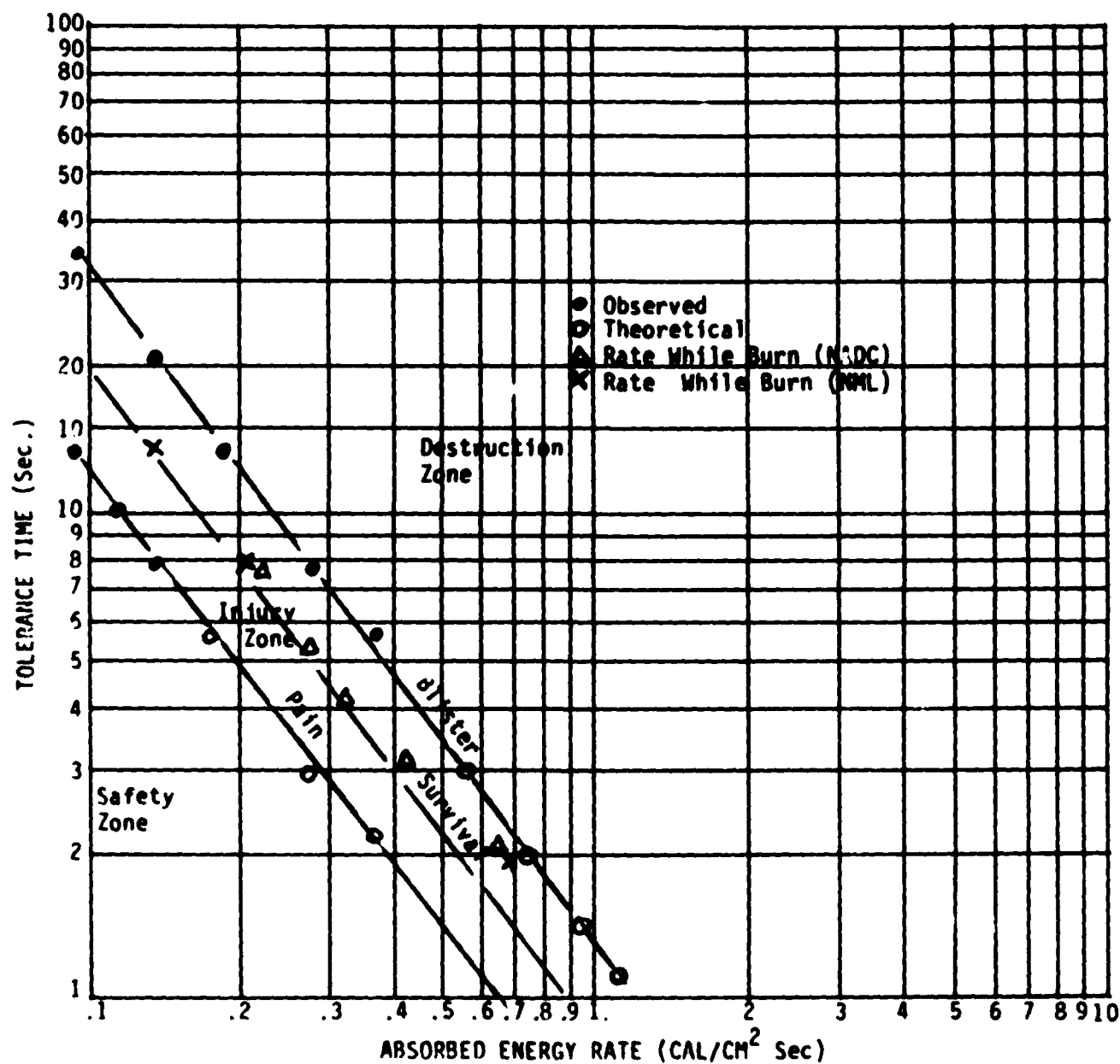


Figure 1. Human Skin Tolerance Time to Absorbed Thermal Energy Delivered in a Rectangular Heat Pulse

SECTION V

CONCLUSIONS

On the basis of laboratory evaluation of worn aluminized fabrics before and after being touched up with "spray-on" aluminum enamels it was found that that the thermal transmission value for the sprayed-on enamels were no better than the worn aluminized fabrics rated very poor. Worn aluminized fabrics in assembly and visually as classified fair, should protect firemen exposed to a heat flux of $1.9 \text{ gcal/cm}^2/\text{sec}$ for 30 seconds. Garments with aluminized surfaces classified as poor should be considered for replacement.

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